OPTICAL ILLUSIONS IN MAN IN THE CASE OF WEIGHTLESSNESS AND OF THE COMBINED EFFECTS OF WEIGHTLESSNESS, ANGULAR AND CORIOLIS ACCELERATION

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During space flights the character of spatial perception, including optical perception, will be affected not only by changes in linear acceleration, weightlessness, but also by angular and coriolis acceleration against a background of changed gravitation, in which it is found that angular and coriolis acceleration lower the quality of work by a human operator during weightlessness to a greater degree than does normal gravity.

Given in the present report are the results of research into human perception of plane figures in the case of weightlessness and under the combined action of weightlessness, angular and coriolis acceleration.

METHOD /181

The state of weightlessness was produced in the cabin of an aircraft flying along a parabolic trajectory.

During horizontal flight with natural gravity, during g-loading and weightlessness the test subjects were presented (one each) the patterns shown in Fig. 1. The angular size of each pattern was 7°, while that of the point was 28 min. The experiments were performed in darkness; the patterns were illuminated and were placed at a distance of 100 cm from the eyes of the test subject. During daylight black figures centered on a 30 cm square were presented at a distance of /182
50 cm from the test subject. The head of the test subject was held vertical with respect to the aircraft. The figures were presented at eye level. The test subjects were able to note the duration of illusory perception by pressing a button, which was registered by an automatic recorder. After each experiment the test subjects gave a detailed account of the observed changes in shape and the displacements of the figure, or individual parts of it. After the flight they prepared a written account, if possible illustrating it with sketches of the changes in the visual objects noted at the respective times.

Participants in the experiments were 28 persons, 20 in the experiment in darkness and 17 during daylight. Each test subject participated in experiments of 6-30 weightlessness periods.

The combined-action experiments, with the test subject exposed to weightlessness, angular and coriolis acceleration, were carried out with 6 men in whom stable optical illusions were observed in preliminary experiments.

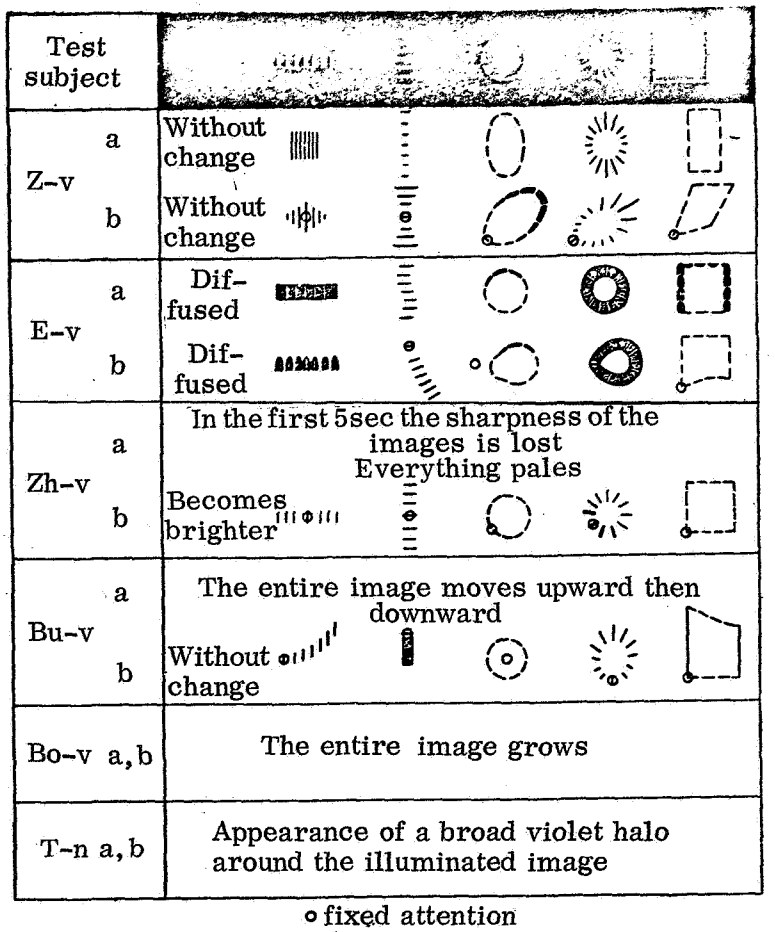

Figure 1. Examples of Optical Illusions Occurring During Weightlessness When Considered Casually (a) and When Considered With a Fixed Stare and Concentrated Attention (b).

The angular and coriolis accelerations were produced by means of a rotating seat, containing the test subject, installed in a darkened portion of an aircraft. A screen fixed to the seat was set up vertically in front of the test subject; on the screen was presented an illuminated image of one of the figures shown in Fig. 1. The effect of angular acceleration was created when the continuously rotating seat was stopped; coriolis acceleration occurred when the test subjects lifted their heads, which had been bent forward, during uniform rotation. In all tests the speed of rotation was 30 rpm. The test subjects lifted their heads for about 0.5 sec; the time of slowdown to stoppage of the seat was 0.5 sec.

Linear acceleration was produced when the test subjects moved "vertically" upward or downward during weightlessness. This created a state of partial weightlessness, positive or negative, equal to approximately 1 g and lasting about 1 sec. Each test subject was subjected to 6-10 experiments.

RESULTS

Of the 28 people who participated in the experiments, 19 noted a change in the observed objects during weightlessness. The reports of these people were rather varied, but from among the various illusory phenomena it is possible to single out individual characteristic types of illusions: 1) an increase in the size of the entire figure; 2) illusory motion of the entire figure; 3) distortion of the figure as a result of an increase of motion of its individual parts; 4) a change in the color intensity of the entire figure or parts of it; 5) the appearance of a violet halo around the illuminated figure.

As reported by the test subjects, the illusions occurred with the onset of weightlessness. The various types of illusions were of differing duration. According to the button-pressing records, the illusions appeared either during the period of decreasing weight or during the first second of weightlessness. In the experiments in which weightlessness was produced immediately after the natural gravity state and g-loading did not precede weightlessness, the illusions were of the same nature as when weightlessness set in after g-loading, but were less sharply pronounced. /183

Twelve people reported apparent increase of the figures under weightlessness. Of these 4 reported uniform increase of the figures, 5 reported increase only in the vertical direction and 3 that the figures seemed to grow in size during vertical flight, but that their horizontal dimensions seemed to decrease, i.e., the figures seemed stretched vertically and narrow. According to the accounts of 5 of the 12 test subjects, individual elements of the figures (broken lines) became somewhat thicker during weightlessness; 5 observed fluctuating expansion of the figures under the same conditions.

Illusions of the described type were rather stable and were maintained throughout the period of weightlessness; they reappeared frequently in succeeding experiments, in many flights.

Thirteen men noted that the visible object blurred, or that a "loop" or "tail," in the downward direction or on either side of the figure appeared. But this phenomenon recurred several times in only 3 men being observed over the entire period of the experiment. Similar illusory blurring of the figure was observed by the remaining 10 test subjects only in the first 3-5 sec of weightlessness, and blurring ceased to occur from the 3rd to 7th period of weightlessness.

Seven people reported that they observed a smooth downward motion of the entire figure or parts of it under weightlessness, but this did not result in disintegration of the figure. When the view was focused on a certain part of the object, this part became stable, but the other parts continued to move. It seemed to three test subjects that the visible image jumped upward abruptly during the transition from g-loading to weightlessness and from weightlessness to subsequent-loading.

Four test subjects noted a decrease in brightness of the figure with the onset of weightlessness. In the case of fixed attention and view focused, the brightness of the object, on the contrary, increased at the focal point, but at some distance from this point the brightness was reduced.

Four test subjects observed doubling of the visual image under weightlessness.

Various illusory phenomena were frequently formed in the same test subjects, and as a result apparent distortions were observed; thus, the "vertical figure" took on a sigma shape, a circle appeared to be similar to a "pear," a "square" was transformed into a "rhomb," etc.

Some test subjects remarked that an illusory decrease in the size of the visible figures occurred during g-loading; i.e., phenomena which are opposite in nature to the illusions observed in weightlessness. /184

In the experiments carried out in darkness, the appearance of stable illusions was more frequent than in the daylight case.

The illusions appeared brightest at the beginning of the first period of weightlessness. Their intensity decreased on repeated exposure to weightlessness.

It is interesting to note that the above-described illusory distortion of figures was observed only by people who in their first few exposures to weightlessness experienced the illusion of falling, accompanied by a sense of fear, although the sensation of falling had ceased to appear in the majority of them by the time of the present experiments as a result of adaptation to weightlessness. More pronounced and stable illusions were found in people who, exposed to weightlessness for the first time, experienced a more intense illusion of falling and a strong sense of fear. People who had experienced other spatial illusions, e.g., upside-down position, side-eying position, upward lift, etc., did not note figure distortion in weightlessness.

Four of the people who had not observed any displacements or changes in shape of the figures during the experiments reported that during weightlessness they saw a broad violet halo form around the illuminated figure, and one test subject felt that a greenish-bluish halo formed. Illusions of this type persisted during the entire period of weightlessness, being repeated in many experiments.

The optical sensations in response to the effect of linear, angular and coriolis acceleration were similar for each form of acceleration in all 6 test subjects.

When a human being is subjected to linear, vertical acceleration, positive or negative, during weightlessness, the optical illusions disappear.

Angular and coriolis acceleration and their after effects during weightlessness, by aggravating the illusions, may cause additional distortion and motion of the observed figures.

During angular acceleration and the period of its aftereffect, the test subjects noted that the figures flickered, the entire figure expanded rhythmically, individual elements of the figure diverged to the sides and moved rhythmically (rotated, tilted), with particular intensity at the point of focus, resulting occasionally in complete disintegration of the figure; also observed was an increase in the horizontal dimensions of the figure and all its parts, motion of the figure, either smoothly or jerkily, to the side opposite to body rotation.

Typical illusions occurring under the effect of coriolis acceleration were inclination or rotation of the entire figure and chaotic motion of individual, broken-line elements of the figure, blurring of the elements, and expansion at the focal point in the case of fixed attention. /185

DISCUSSION

Upward motion of visible objects with decreasing gravity, in our opinion, may be a result of lowering of the crystalline lens due to weakening of Zinn's ligament, because of intensification of the accommodation effort of the ciliary muscle.

Evidence of an increase in the accommodational capabilities is provided by our discovery, during weightlessness, of the approach of "near," and especially of "very near" points of clear vision. Symptoms of myopia were also observed in studying eye refraction in test subjects who considered objects at a distance of 8 m during weightlessness. Tension of the ciliary muscle is, probably, a result of the parasympathicotropic effect of weightlessness, which was detected both during prolonged (Gazenko, Bayevskiy) as well as short-term (Kitayev-Smyk) action.

Intensification of accommodation doubtlessly causes compensational effects. As is well known, inverse afferentation in this case informs the consciousness of signals that the visible object has either expanded or receded. In our experiments, when the aircraft cabin was perceived constantly, the test subjects perceived these signals during weightlessness as evidence of the expansion of the visible objects. When extra-cabin objects known to the observer were examined, the attenuating accommodation will lead to the illusory perception that they are moving away. The correctness of our assumption has been proved in actual space flight by MacDivitt, to whom the distance to the carrier rocket, visible through an illuminator, seemed to be 5 times greater than it was in fact.

Illusory "magnification-recession" may also be caused by additional effort toward divergence of the eyes when the angle of vision at which the object is sighted does not change. However, as demonstrated by our determination of the nearest point of binocular vision, this is not observed during short-term weightlessness. On the contrary, we observed weakening of convergence, which must be compensated for by reinforcing convergence in order to keep the angle of inclination of the optical axes constant. It is known that illusory approach or decrease in size of a visual object occurs when vestibulary stimuli result in additional forces of convergence. Consequently, during weightlessness two stimuli of opposite effect operate to affect perception of the surrounding space. Intensification of accommodation and the necessity of compensating for it may lead to illusory "magnification-recession" of visual objects, while a decrease of convergence and of its compensation lead to illusory "reduction - approach" of these objects. As shown by our experiments under short-term weightlessness and the observations of MacDivitt under the prolonged effect of weightlessness, the first illusion gains the upper hand. Probably the considerable difficulties of MacDivitt in determining distance in space are explained by competition between the two influences. /186

Interruption of the functions of the oculomotor system during weightlessness was reported on the basis of analysis of oculograms taken from the cosmonauts

in flight. This is also testified to by the doubling of the visible image described in the present paper.

Insofar as the mechanisms of the other illusions observed in our experiments are concerned, only assumptions can be made here too. It is possible that the appearance of the violet halo during weightlessness is a result of chromatic aberration when accommodation is intensified. The occurrence of myopia may be somewhat related to the illusions observed by several people which may be explained as variations in the peripheral sections of the optical analyzer.

The illusory distortions of figures observed in the absence of gravity are doubtlessly attendent upon changes in central mechanisms.

Various distortions of optically perceived space were described during the action of stimulating and inhibiting effects applied to various levels of the vestibular and cutaneous muscle analyzers.

According to the data of Merkulov and Zhabotinskaya, patients with affected reticular formation of the stem without ocular pathology complained of apparent scintillation, pulsation or vague fluctuating vision of objects.

When damage is incurred in the region of the posterior longitudinal fasciculus, patients are afflicted with "Pieck's illusion"; it seems to them that walls are bending out, and that people around them can pass through the walls into the next rooms (cited after Bing and Bruckner). It is believed that in such cases there is a lack of correspondence between optically and vestibularly governed perception of space as a result of attenuation or interruption of pulses from the vestibular apparatus to the nuclei of the oculomotor nerves.

Many reports are available on the occurrence of optical illusions similar to those described in the present paper when certain sectors of the cortex of the cerebral hemispheres are stimulated directly or destroyed. In this respect of special interest is the temporal-parietal region of the cortex. When it is stimulated by electric current during an operation, familiar objects seem to the patients to be frightfully distorted, approaching or receding. Hoff and Kamin reported that a patient with a skull defect in the parieto-occipital region on the left, when the skin was cooled at the defect point with ethyl chloride, observed the entire visible space to be shifted to a side opposite to the damaged side, letters appeared to be distorted and piled up one on the other.

Characteristic of people with a diseased center in the temporal lobe, the region of vestibular representation, are illusory, fantastic distortion of visible objects and their apparant plurality, as well as motion and pulsation; the distortions may be provoked by cooling the neck and the pluraity by vestibular nystagmus. /187

The cited facts indicate the special part played by the temporal-parietal cortex in organizing the process of optical perception when the latter is coordinated with information arriving from the vestibular and cutaneous muscle analyzers.

In Petzl's opinion, field 39 (the inferior parietal region) is the seat of mechanisms whose significance is found to consist in suppressing superfluous

pulses coming from the various afferent systems (especially from the vestibular) into the visual sphere. When these superfluous pulses penetrate the sphere, the acuity of optical perception is disturbed. The same opinion is supported by the work of Hernandes - Peon, who used electrophysiological methods of investigation, arriving at the conclusion of the existence in the human brain of an entire system of filters which prevents hyperactivity of the sensory nervous and, thus, prevents excessive bombardment of the brain by afferent pulses.

On the basis of numerous experiments with animals, Khananashvili also confirms the fact that the "posterior section of the parietal region (field 7) in higher mammals has a definite significance in the process of interaction between different cortical analyzers. This region promotes the normal flow of nervous processes which take care of complex analysis and synthesis of optical and acoustic stimuli."

Thus, based on the cited literary data, it can be assumed that the optical illusions described in this paper, occurring in a number of people in the initial period of the effect of weightlessness, are of gravireceptor, primarily labyrinth origin and take place against a background of change of the central, possibly of the corticofugal influences regulating the influx of gravirecptor afferentation and coordinating this activity with the optical analyzer system. It does not seem possible at the present time, due to the lack of the necessary experimental data, to localize these variations, to establish how high up in the cerebral system they occur.

As a confirmation of the expressed opinion concerning the central mechanism by which the interruptions of vision described in this paper occur let us cite the fact that in the present paper as well as numerous investigations of an "oculogravic" illusion similar in origin to the phenomena described here, interruptions of optical perception took place only when the force of gravity was changed in darkness, when, as is well known, slowdown of the cortical functions is observed. /188

Without going into detail in the present report on a discussion of the reasons why optical illusions were noted only by people who, making their first acquaintance with weightlessness, experienced sensations of "falling", "collapse", fear and disorientation, replaced by varying degree of euphoria, let us recall how these sensations are similar to the "end of the world" syndrome described by Shmar'yan in people whose temporal cerebral lobes have been damaged. Typical of such patients is also the feeling of "falling into an abyss", accompanied by disorientation. Euphoria, with the phenomenon of sensory disintegration, has been observed in patients having tumors of the temporal lobe with simultaneous damage to the diencephalic region.

It is also known that when people who experience sensations of falling and fear at the beginning of weightlessness are repeatedly exposed to these conditions, they have, as a rule, no vegetative disturbances, in contrast with test subjects who, during weightlessness, had no emotional reactions, optical disturbances and did not suffer from vegetative disruptions. These characteristics permit us to assume that there exist groups of people whose sensory interrelationships differ in character under such conditions.

Stabilization of the visual image at the point of focus in the case of fixed attention, as described in this paper, is understandable from the viewpoint of psychological as well as electrophysiological concepts. The reliability of the information obtained increases thanks to activation of the optical cortex and of corticofugal effects on systems which filter the excess information. Interesting is the fact that when the semicircular canals are stimulated during weightlessness, concentration of attention increases illusory dislocation and distortion at the point of focus. In the light of the clinical material presented above it must be assumed that in the latter case that the mechanisms by which excess information is filtered out cannot cope with the higher vestibular influences reaching the cortex in this case. Activation of the cortex during concentrated attention only deepens the conflict between the optical and vestibular information.